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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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AERODYNAMIC ROLLING AND YAWING MOMENTS PRODUCED BY FLOATING WING-TIP AILERONS, AS MEASURED BY THE SPINNING BALANCE

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AERODYNAMIC ROLLING AND YAWING MOMENTS PRODUCED BY FLOATING WING-TIP AILERONS, AS MEASURED BY THE SPINNING BALANCE

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SUMMARY

The investigation described in this report was made to determine the effectiveness of floating wing-tip ailerons as an airplane control in the spin. In these tests the ailerons, not being balanced, were set parallel to the axis of rotation, which is probably very nearly the attitude that balanced floating ailerons would assume in a spin.

The tests were made with the spinning balance in the N.A.C.A. 5-foot vertical tunnel. The model was tested with and without the ailerons in 12 spinning attitudes chosen to cover the probable spinning range.

Rolling- and yawing-moment coefficients are given as measured for the model with and without the ailerons, and computed values are given for the ailerons alone.

The addition of floating wing-tip ailerons to the model doubled the rolling-moment coefficient and increased the yawing-moment coefficient by 0.05 and more. Both moments were in a sense to oppose the spin.

INTRODUCTION

The necessary condition for a steady spin is that all aerodynamic forces and moments about any set of axes must exactly equal and oppose the gyroscopic moments, weight of the airplane, and centrifugal force.

The effects, on a spin, of changes in the aerodynamic forces are usually of secondary importance because they are balanced by small changes in attitude or velocity without materially affecting the spin. A moderate change in aerodynamic rolling moment during a spin is usually balanced by a change in sideslip. An increase in the pitching moment (diving moment), if it is not applied too suddenly, is usually balanced by an increase in rotational velocity. An increase in damping in yaw, however, is usually balanced by a decrease in rotational velocity. This decrease in rotational velocity decreases the gyroscopic stalling moment and the airplane will spin at a lower angle of attack or it may recover from the spin. In other words, a damping moment in yaw is the only force or moment which usually cannot be balanced by small changes in attitude or velocity without materially affecting the spin. It is also true that if any aerodynamic moment is changed sufficiently either the attitude of the airplane or the rotational velocity will be such as to destroy the balance of the moments or forces and a steady spin will be impossible.

A study of methods for obtaining suitable damping in yaw indicated that floating wing-tip ailerons give large rolling and yawing moments (airplane axes) opposing the spin, even with the controls set partly with the spin. These moments should be sufficient to prevent an otherwise normal airplane from attaining an uncontrolled spin; they would probably entirely prevent any spin if the controls were held neutral.

Wind-tunnel investigations have shown that floating wing-tip ailerons give lateral control at all angles of attack (references 1 to 5, inclusive), and that with controls neutral they give large damping moments in roll about the wind axes (references 2, 3, and 6). The performance characteristics of floating tip ailerons are at present considered rather unsatisfactory because they add so much extra span and area to the wing for control purposes only and because the control forces may be rather large (references 1 to 3, inclusive). However, it appears that an aileron balance can be developed that will allow the increased span and area to be used as a lifting surface as well as a control, and the control forces could be reduced. With a suitable aileron balance the wing-and-aileron cambination should give nearly as good climb and lift characteristics as a plain wing of the same total area.

The present investigation was made with the spinning balance in the N.A.C.A. 5-foot vertical wind tunnel to determine the aerodynamic forces and moments given by floating wing-tip ailerons on a model operating in spinning attitudes.

MODEL AND APPARATUS

The model used in these tests was a low-wing monoplane. Side and plan views are given in figure 1. The areas of the tail surfaces and the length of the fuselage represent average present-day practice. The wing, of a symmetrical section, was tapered 2:1 in plan form and 1.55:1 in thickness, the thickness being 18.5 percent of the chord at the root section. The span of the wing was 30 inches and the aspect ratio was 6. The dihedral was such that the maximum upper-surface section ordinates were in one plane.

The ailerons were made as a continuation of the wing at the tips and their area was 15.1 percent of the wing area. They were rigidly interconnected by a rod running straight through the wing, located 20 percent of the chord back of the leading edge and on the chord line of the section at the tip of the wing. Because of the dihedral in the wing the ailerons rotated about an axis which was not the center line of the thickness of the sections. The ailerons were not balanced either statically or dynamically, so for these tests they were locked parallel to the axis of the spin. This practice was considered allowable because the geometry of the spin indicates that balanced ailerons would float very nearly in this position except for sideslip and interference effects between the aileron and wing.

The spinning balance, which measures all six components, is described in reference 7 and the vertical wind tunnel is described in reference 8.

TESTS

Tests were made with and without the ailerons in each of the attitudes defined by the following table:

α (degrees)	β (degrees)	Rotational velocity Ω (radians per second)	Radius of spin (inches)	Tunnel air speed (ft./sec.) w"	$\frac{p}{\Omega}$	$\frac{q}{\Omega}$	$\frac{r}{\Omega}$
40	6	27.1	4.36	65	0.7294	0.2511	0.6359
40	0	27.1	4.36	65	.7457	.1484	.6495
40	-10	27.1	4.36	65	.7534	-.0253	.6571
50	10	28.5	3.28	65	.6018	.2882	.7448
50	0	28.5	3.28	65	.6250	.1178	.7716
50	-10	28.5	3.28	65	.6284	-.0561	.7758
60	10	31.1	2.14	60	.4697	.2625	.8429
60	0	31.1	2.14	60	.4851	.0909	.8697
60	-10	31.1	2.14	60	.4853	-.0834	.8704
70	10	29.2	.97	50	.3280	.2201	.9187
70	0	29.2	.97	50	.3363	.0465	.9406
70	-10	29.2	.97	50	.3335	-.1279	.9341

where p, q, and r are the rotational velocities in radians per second about the X, Y, and Z axes, respectively; and β is the angle between the resultant wind and its projection on the XZ plane, positive in a right spin with inward sideslip

The above attitudes were computed for each angle of attack from a balance between assumed values of normal force and pitching moments due to air forces, and the weight of the airplane, the centrifugal force, and the gyroscopic pitching moment due to the rotation.

Both the elevator and the rudder were neutral for all tests. The tunnel air speed was reduced at angles of attack of 60° and 70° because of the high rate of rotation. The Reynolds Number, based on a 5-inch chord and an air speed of 65 feet per second, was about 165,000.

RESULTS

The coefficients of rolling (C_l) and yawing (C_n) moments obtained with and without the ailerons are given for right spins in figures 2 and 3. The changes in force and pitching-moment coefficients are considered to be of negligible importance.

The coefficients in each case were obtained by the following relations:

$$C_l = \frac{L}{\frac{1}{2}\,\rho\,V^2\,S\,b}$$

$$C_n = \frac{N}{\frac{1}{2}\,\rho\,V^2\,S\,b}$$

where L and N are the moments

S is the area of the wing without the ailerons

b is the span of the wing without the ailerons

Test results can usually be repeated within ±0.005 for C_n and C_l.

DISCUSSION

Figure 2 shows that the rolling moments opposing the spin are about twice those given by the model without the ailerons. The addition of this rolling moment would make the airplane spin with considerable outward sideslip or it might prevent the spin if the difference in moments of inertia about the Y and Z axes is within the range of that for ordinary airplanes.

Figure 3 shows that, with the ailerons attached, the yawing moment opposing the spin is large, the smallest value of the coefficients being 0.075. It is generally agreed that the aerodynamic yawing moment is the most important factor in the control of a spin; a value of the coefficient of 0.03 would probably prevent a dangerous spin, and a value of 0.06 has been given as being sufficient to prevent any airplane from attaining a dangerous spin (reference 9).

It is doubtful if sufficient rotational velocity could be obtained with the large damping moments in yaw to balance the aerodynamic pitching moments in any spinning attitude. A spin might be developed by putting the controls with the spin, but recovery would be immediate when the controls were moved to neutral. However, there still remains the possibility that recovery from a spin might be impossible if the airplane is of an unconventional design.

Values of C_l and C_n were computed by assuming that each aileron was an individual airfoil of aspect ratio 1.51 operating at the angle of attack and air speed it would have attained if there had been no interference from the rest of the model. These values are given in figures 2 and 3 for comparison. The computed values of rolling- and yawing-moment coefficients are considerably larger than the measured values. This difference is probably due to the interference between the ailerons and the wings.

CONCLUSIONS

1. Floating wing-tip ailerons give very large rolling and yawing moments opposing the spin when used on an airplane in spinning attitudes if they are held neutral, i.e., if both ailerons are held in the same plane and allowed to rotate about the lateral axis of the wing.

2. With the ordinary type of airplane fitted with floating wing-tip ailerons, it is very improbable that a balance in a spin could be obtained with the aileron controls neutral. If a spin were obtained when the controls were with the spin, recovery would very probably be immediate and positive when the controls were moved to neutral.

3. Computed values of rolling- and yawing-moment coefficients for the ailerons only (neglecting aileron-wing interference) are considerably larger than the measured values.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 30, 1934.

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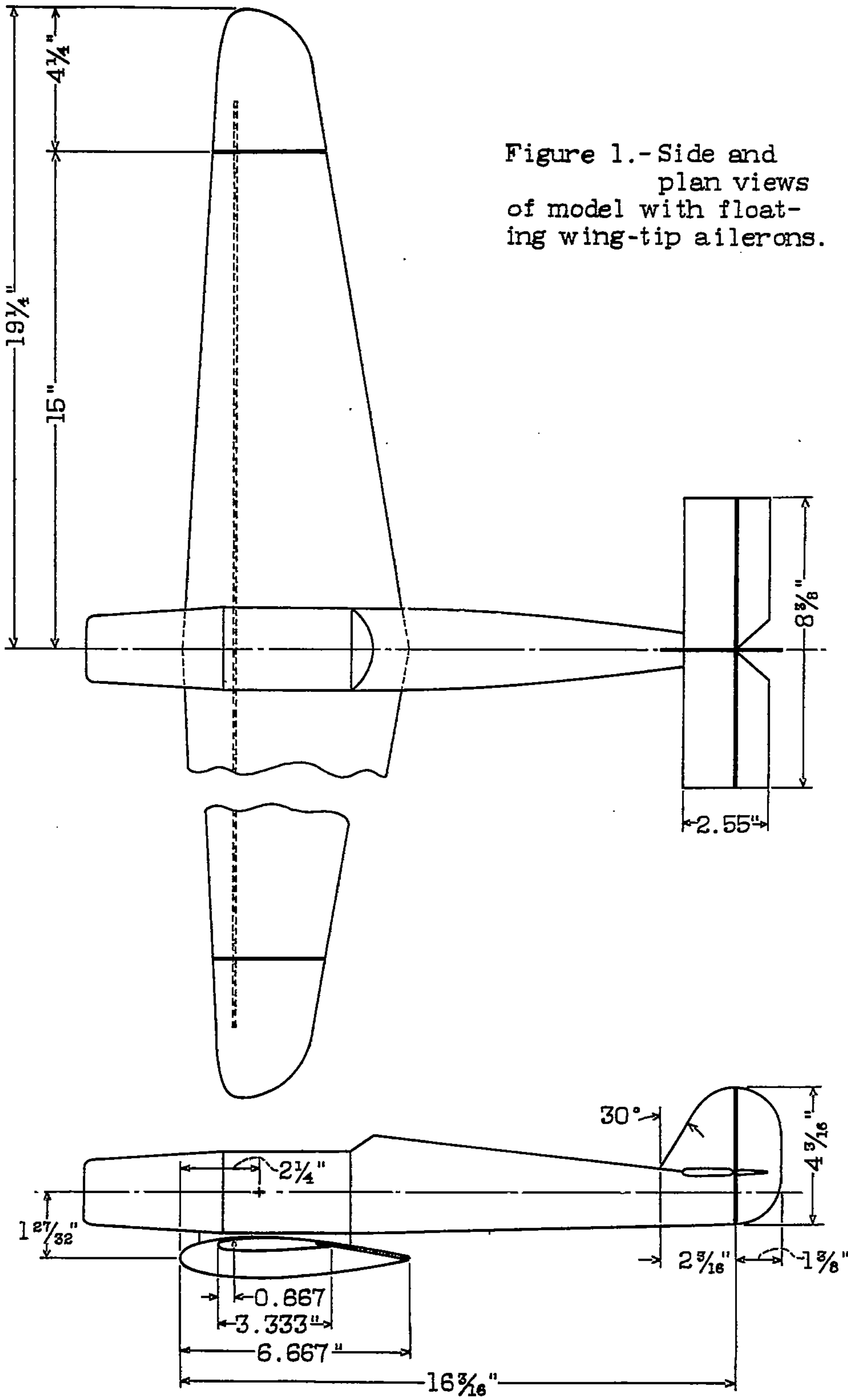

Figure 1.- Side and plan views of model with floating wing-tip ailerons.

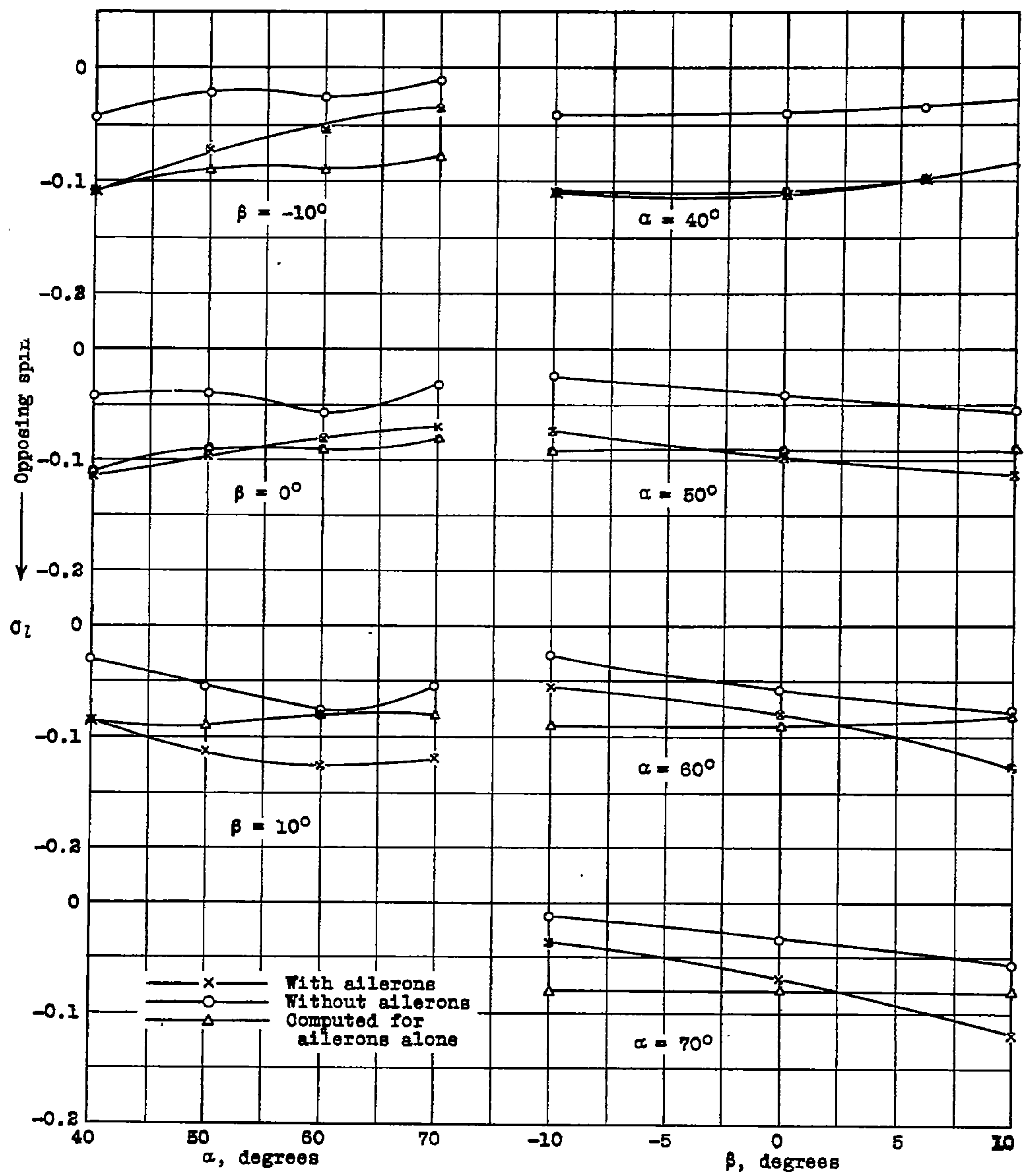

Figure 2.- Rolling-moment coefficients, body axes, for model with and without floating wing-tip ailerons, and computed values. Right spin.

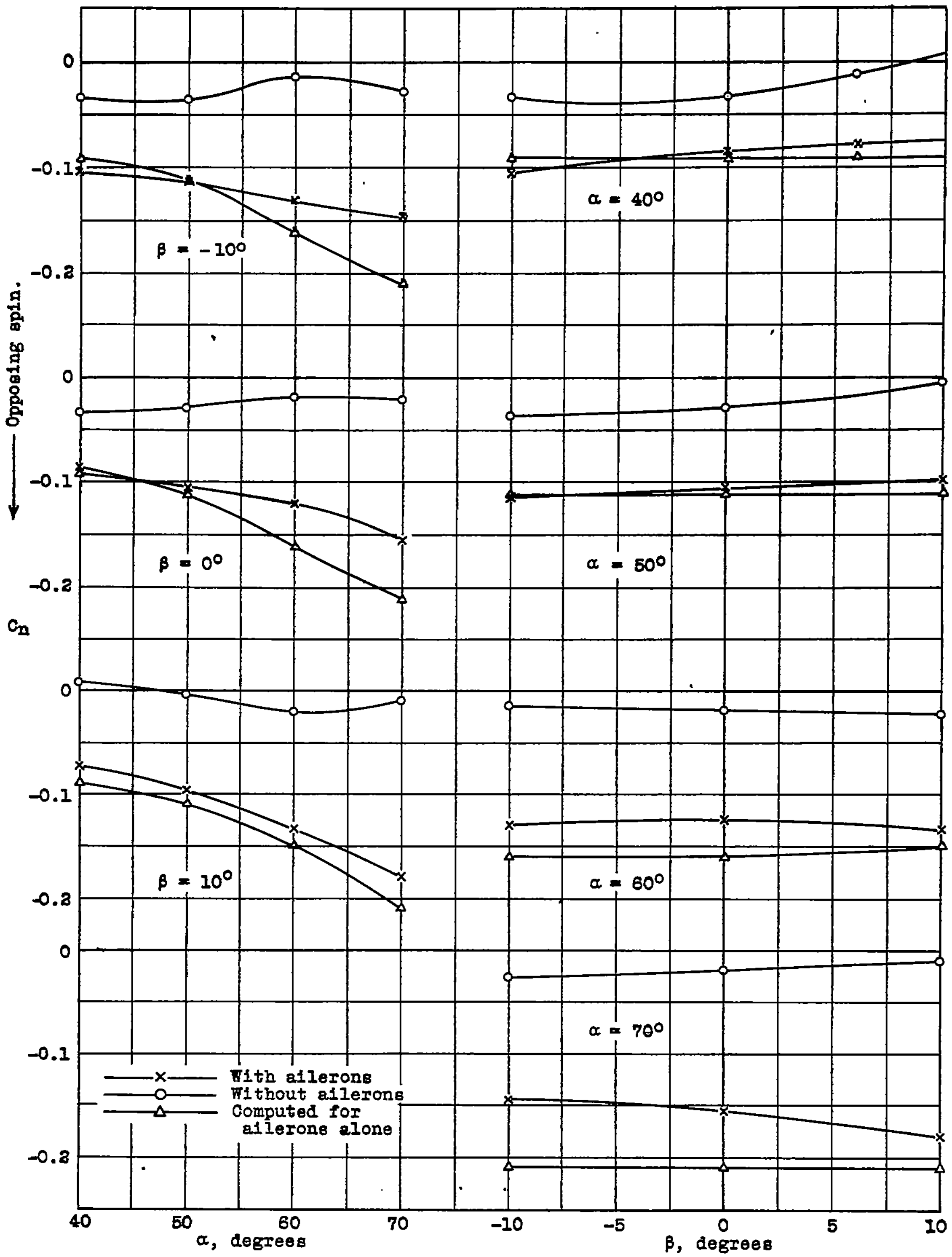

Figure 3.- Yawing-moment coefficients, body axes, for model with and without floating wing-tip ailerons, and computed values. Right spin.